* Laws:

1- Major diameter:

- $D_{major} = R_f - R_i$ [Hand tools & Abbe vertical]
  - ↳ Using B.Gs ($R_i = R_{B.G.1} + R_{B.G.2} + R_{zero} + R_{anvils}$ (abbe))
- $D_{major} = R_2 - R_1$ [Microscope & projector]

2- Minor diameter:

- $R = R_2 - (R_1 - R_{B.G.})$

$\psi = \tan^{-1}\left(\frac{lead_{std}}{\pi D_{eff.}}\right)$ ↳ Using B.Gs ($R_1 = R_{B.G.1} + R_{zero} + R_{anvils}$) [Hand tools]

$D_{minor} = R \cos\psi$

- $D_{minor} = R_2 - R_1$ (Consider helix angle) [Microscope & projector]

3- Effective diameter:

- $D_e = R_2 - R_1$ [Pitch dia. anvils]
  - ↳ $R_1 = R_{anvils} + R_{zero}$
- $d_{best} = \frac{P_{std}}{2} \sec\theta_{std}$ → larger [3 wires & Abbe vertical]

$d = \frac{R_2 - R_1}{2}$ ↳ R_{zero} (using wires only)

$S = R_2' - R_1$

$D_e = S - d(1 + \operatorname{cosec}\theta_{std}) + \frac{P_{std}}{2}\cot\theta_{std}$

$A = \frac{d}{T+d} = \frac{d}{S-d}$

$e = \frac{\cos\theta_{std}\cot\theta_{std}}{2\pi^2} \times \frac{L^2}{d} \times A^2(1 + A\sin\theta + A^2\sin^2\theta)$

$C = 0.001 \frac{F^{2/3}}{D_e^{1/3}}$

$D_{e_{corrected}} = D_e - e + C$

- $D_e = R_2 - R_1$ (Consider helix angle) [Microscope & projector]

4- Included angle measurement:

- Using values of eff. diameter and move dw_2 as well

$$\theta = \sin^{-1}\left[\frac{dw_2 - dw_1}{(y_2 - dw_2) - (y_1 - dw_1)}\right]$$ [Hand tools & Abbe vertical]

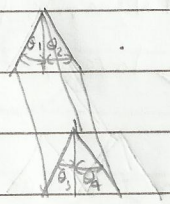
$\theta_{included} = 2\theta$

- Direct measurement [Microscope & projector]

5- Flank angle measurement:

- Direct measurement and eliminate misalignment error

$$\theta_L = \frac{\theta_1 + \theta_3}{2}, \quad \theta_R = \frac{\theta_2 + \theta_4}{2}$$

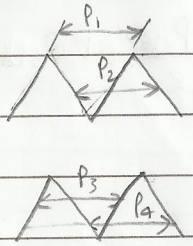


[Microscope & projector]

6- Pitch measurement:

- $P = R_2 - R_1$ and eliminate misalignment error

$$P = \frac{\sum_{i=1}^{4} P_i}{4}$$



7- Virtual effective diameter:

$$V.E.D. = D_e + \underset{\text{flank}}{\Delta\theta} + \Delta P = s + d(1 + \operatorname{cosec}\theta_{std}) + \frac{P_{std}}{2}\cot\theta_{std} + 0.0131P(|\delta\theta_R| + |\delta\theta_L|) + \underset{\text{or } 0.0105}{} + \frac{P}{2}(\cot\phi - \cot\theta) + \Delta P_m \cot\theta_{std} \quad \ldots = 0.$$

[From std values]

*Problems:

1- Metric thread

An external thread of ISO metric form has the following dimensions and errors: Simple effective diameter = 21.905 mm, Pitch =3.000 mm, Max. Pitch error = 0.025 mm, Right hand flank error = 5 min of an arc and the left hand flank error = 6 min of an arc. Determine the virtual effective diameter of the given thread.

$D_e = 21.905$ mm

$P = 3$ mm

$\Delta P_{max} = 0.025$ mm

$\delta\theta_R = 5'$

$\delta\theta_L = 6'$

Error in flank angle of metric thread $= 0.0131 P_{std} (\delta\theta_R + \delta\theta_L)$

$\Delta\theta = 0.0131 \times 3 (5+6) \times \frac{1}{60} = 0.007$ mm

Error in pitch $= \Delta P_{max} \cot\theta_{std} = 0.025 \cot 30^\circ = 0.043$ mm

$V.E.D. = D_e + \Delta\theta + \Delta P = 21.905 + 0.007 + 0.043 = 21.955$ mm

2- P = 5 mm, metric thread

In measuring the pitch diameter of a 52 x 5 mm metric plug screw gauge, the average of the readings taken was:

- Reading over standard cylinder = 25.0033 mm
- Diameter of standard cylinder = 15.0030 mm
- Readings over each of the three wires = 13.2007, 13.2002 and 13.2000 mm
- Readings over thread with the three wires in three different places= 64.0272, 64.0270 and 64.0275 mm.

***Calculate the corrections for rake and compression errors, assuming a measuring force of 2.45 N.**

***Calculate the effective diameter, taking into consideration the calculated rake and compression errors.**

$R_1 = R_{cyl.} - D_{cyl.} = 25.0033 - 15.0030 = 10.0003$ mm

$R_{av_d} = \frac{\sum_{i=1}^{3} R_i}{3} = \frac{13.2007 + 13.2002 + 13.2}{3} = 13.2003$ mm

$2d = R_{av_d} - R_1 = 13.2003 - 10.0003 = 3.2$ mm

$d = \frac{3.2}{2} = 1.6$

$R_{av_s} = \frac{64.0272 + 64.027 + 64.0275}{3} = 64.0272$ mm

$S = R_{av_s} - R_1 = 64.0272 - 10.0003 = 54.0269$ mm

$A = \frac{d}{S-d} = \frac{1.6}{54.0269 - 1.6} = 0.0305$

$e = \frac{\cos 30^\circ}{2\pi^2 \tan 30^\circ} \times \frac{S^2}{1.6} \times (0.0305)^2 \left[1 + 0.0305 \sin 30^\circ + (0.0305 \sin 30)^2 \right]$

$e = 0.0018$ mm

$D_e = S - d(1 + \text{cosec}\,\theta) + \frac{P_{std}}{2}\cot\theta_{std}$

$= 54.026g - 1.6(1 + \text{cosec}\,30°) + \frac{S}{2}\cot 30° = 53.557\,0\text{mm}$

$C = 0.001\,\frac{F^{2/3}}{De_{c,e}^{1/3}} = 0.001 \times \frac{(2.45)^{2/3}}{(53.557 + 0.0018)^{1/3}} = 0.00048\text{ mm}$

$D_{e\,corrected} = De - e + C = 53.557 - 0.0018 + 0.00048 = 53.556\text{ mm}$

3.

Calculate the virtual effective diameter of M16*1.5 screw if the reading over three wires placed over the thread is 17.019 mm. The wires having 1.35 mm diameter, the flank angles of the thread were 29.5° and 30.5° , and the pitch of the thread when checked along the teeth were:

1.502	1.496	1.504	1.501	1.500	1.503	1.495	1.502	mm

If this screw is to fit in a nut having 14.260±0.035 mm pitch diameter, check whether the screw will fit fully, partially or will not fit at all when engaged with the nut,

Metric thread

$P = 1.5$ mm

$S = 17.019$ mm

$d = 1.35$ mm

$\theta_R = 29.5°$

$\theta_L = 30.5°$

$P = 1.502 \quad 1.496 \quad 1.504 \quad 1.501 \quad 1.5 \quad 1.503 \quad 1.495 \quad 1.502$ mm

$D_{e,nt} = 14.26 \pm 0.035$ mm

$\Delta\theta_R = \theta_R - \theta_{std} = 29.5 - 30° = -0.5°$

$\Delta\theta_L = \theta_L - \theta_{std} = 30.5° - 30° = 0.5°$

$\Delta\theta = 0.0131\,P_{std}(|\Delta\theta_R| + |\Delta\theta_L|) = 0.0131 \times 1.5(0.5 + 0.5) = 0.020$ mm

$\Delta P_i = P_i - P_{std}$

$\Delta P = +0.002 \quad -0.004 \quad +0.004 \quad +0.001 \quad 0 \quad +0.003 \quad -0.005 \quad +0.002$ mm

$\Delta P_{max\,acc.} = 0.004 - (-0.005) = 0.009$ mm

$\Delta P = \Delta P_{max}\cot\theta_{std} = \frac{0.009}{\tan 30°} = 0.016$ mm

$V.E.D. = D_e + \Delta\theta + \Delta P = S - d(1 + \text{cosec}\,\theta) + \frac{P_{std}}{2}\cot\theta_{std} + \Delta\theta + \Delta P$

$= 17.019 - 1.35\left(1 + \frac{1}{\sin 30°}\right) + \frac{1.5}{2\tan 30°} + 0.02 + 0.016$

$V.E.D = 14.304$ mm

$V.E.D_{min} = 14.225$, $V.E.D_{max} = 14.295$ mm

$V.E.D. > V.E.D_{max}$ → Not fits partially till 2nd tooth

14.304 − 0.016 = 14.288 (0) ✓
14.29 + 0.002 = 14.292 (1) ✓
14.294 + 0.004 = 14.298 (3) ✗

4-

Three wire set of nominal size 1.35 mm was used to inspect the pitch diameter of M16*2 screw plug. The used external micrometer has a scale value of 0.01 mm, measuring range 25mm, and zero reading of 0.05mm. Knowing that the maximum and minimum permissible allowance of the pitch diameter is +0.21 mm and -0.00 mm, determine the extreme readings of the micrometer such that the readings correspond to the accepted screw lies-in-between.

Metric thread

$P_{std} = 2$ mm , $D_e = D_o - 0.866 \times 2P = 12.536$ mm

$d = 1.35$ mm

S.V. $= 0.01$ mm

Range $= 25$ mm

$R_{zero} = 0.05$ mm

$All._{D_e} = {}^{+0.21}_{-0.00}$ mm

$R = S + \text{zero error} + \text{allowance}$

$= D_e + d(1 + \operatorname{cosec}\theta_{std}) - \frac{P_{std}}{2}\cot\theta_{std} + R_{zero} + all.$

$= 12.536 + 1.35\left(1 + \frac{1}{\sin 30^\circ}\right) - \frac{2}{2\tan 30^\circ} + 0.05 {}^{+0.21}_{-0.00}$

$R_{min.} = 14.904$ mm

$R_{max.} = 15.114$ mm

5-

On a T.M.M. the pitch of a screw was measured and the readings (mm) were as follows:

1st. Side	5.02	7.04	9.05	11.03	13.00	14.98	17.02	19.04	21.00	23.03
2nd. Side	6.01	8.03	10.05	12.05	14.02	16.05	18.03	20.05	22.07	24.07

If the screw is a perfect screw in other parameters and it'll fit a nut (perfect nut) of 10 mm height. Will this screw engages fully with the nut or partially; and if partially how many teeth will be engaged? Given that the permissible allowance of the pitch diameter is ±0.06 mm.

$P_{std} = \frac{H}{\text{no. of readings}} = \frac{10}{10} = 1$ mm

$P = R_2 - R_1$

P(mm) 0.99 0.99 1 1.02 1.02 1.07 1.01 0.99 1.07 1.04

$P_{av.} = \frac{\sum_{i=1}^{10} P_i}{10} = 1.02$ mm

$\Delta P_i = P_i - P_{std} = P_i - 1$

ΔP(mm) −0.01 −0.01 0 +0.02 +0.02 +0.07 +0.01 −0.01 +0.07 +0.04

$\Delta P_{max.\,acc.} = +0.07 - (-0.01) = 0.08$ mm

$\Delta P = \Delta P_{max.\,acc.} \cot\theta_{std} = 0.08 \cot 30^\circ = 0.139$ mm (Metric thread)

$\Delta P >$ Allowance $\Rightarrow$ Nut will fit partially

Tooth no.	1	2	3	4	5	6
$\Delta P_{accumulated}$ (mm)	0.01	0.02	0.02	0.04	0.06	0.013

5 tooth only fit from nut